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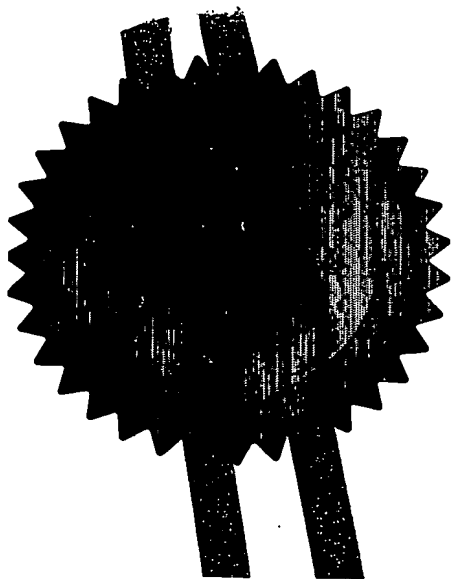
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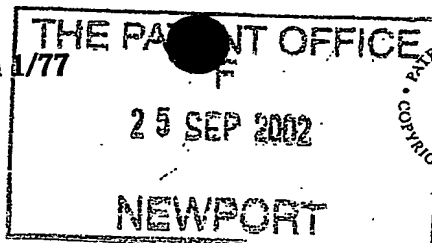
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# Request for grant of a patent

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1. Your reference

for.2393.uk.dk.acf

2. Patent application number

(The Patent Office will fill in this part)

0222211.5

25 SEP 2002

3. Full name, address and postcode of the or of each applicant (underline all surnames)

Fortkey Limited  
Elvingston Science Centre  
Gladsmuir  
East Lothian EH33 1EH

Patents ADP number (if you know it)

8471096001

If the applicant is a corporate body, give the country/state of its incorporation

United Kingdom

4. Title of the invention

Imaging and measurement system

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

Kennedys Patent Agency Limited  
Queen's House, Floor 5  
19-29 St Vincent Place  
Glasgow G1 2DT

Patents ADP number (if you know it)

8058240001

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Country

Priority application number  
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Date of filing  
(day / month / year)

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing  
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8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:

Yes

- a) any applicant named in part 3 is not an inventor, or
  - b) there is an inventor who is not named as an applicant, or
  - c) any named applicant is a corporate body.
- See note (d))

**Patents Form 1/77**

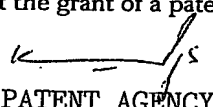
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Priority documents	---
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Statement of inventorship and right to grant of a patent (Patents Form 7/77)	---
Request for preliminary examination and search (Patents Form 9/77)	---
Request for substantive examination (Patents Form 10/77)	---
Any other documents (please specify)	---

11. I/We request the grant of a patent on the basis of this application.

Signature		Date
KENNEDYS PATENT AGENCY LTD		24 September 2002

12. Name and daytime telephone number of person to contact in the United Kingdom

Arlene Campbell - 0141 226 6826

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1 IMAGING AND MEASUREMENT SYSTEM

2

3 The present invention relates to video mosaicing and, in  
4 particular, to a method and system for providing a highly  
5 spatially accurate visualisation of a scene from which  
6 measurements can be taken.

7

8 A video mosaic is a composite image produced by stitching  
9 together frames from a video sequence such that similar  
10 regions overlap. The output gives a representation of  
11 the scene as a whole, rather than a sequential view of  
12 parts of that scene, as in the case of a video survey of  
13 an area. One of the best known applications of this  
14 technique being the creation of panoramic photographs of  
15 a scene.

16

17 In publishing and image retouching applications the  
18 mosaics are manually generated which is a costly and time  
19 consuming process. More recently a system for  
20 automatically generating a mosaic has been suggested, US  
21 Patent 5,649,032, which provides the possibility for  
22 real-time video mosaicing. This Patent details  
23 applications for display of an image, compression of an  
24 image for storage and when constructed, to a surveillance

1 system suitable for determining enemy movement on a  
2 battlefield, a burglar entering a warehouse, and the  
3 like.

4  
5 Video mosaics constructed in this fashion are not suited  
6 to applications involving the making of accurate  
7 measurements for the following reasons.

8  
9 Firstly, it is vital to perform a camera calibration  
10 procedure to estimate and hence correct for the  
11 distortions caused by the internal geometry of the  
12 camera. Uncorrected, these distortions will significantly  
13 degrade the accuracy of any measurements made from the  
14 mosaic.

15  
16 Secondly, the nature of the accumulation of errors in the  
17 estimation of rotations between frames leads a drift  
18 characteristic of a "random walk" which will seriously  
19 degrade the accuracy of long range measurements.

20  
21 Finally, non-translational changes in the camera position  
22 (e.g. pitch and roll) will lead to perspective changes  
23 between frames which will also degrade the positional  
24 accuracy of the constructed mosaic. Although it is  
25 possible to estimate the variation in camera attitude  
26 from the video frames, the accumulation of the associated  
27 errors would again lead to degradation in measurement  
28 accuracy.

29  
30 It is an object of the present invention to provide a  
31 measurement system and method using video mosaicing which  
32 obviates or mitigates at least some of the disadvantages  
33 in the prior art.

1 It is further object of at least one embodiment of the  
2 present invention to provide a measurement system and  
3 method to provide a highly spatially accurate  
4 visualisation of a scene from which measurements can be  
5 taken.

6  
7 It is a still further object of at least one embodiment  
8 of the present invention to provide a measurement system  
9 and method from which one can make measurements of a  
10 scene to millimetre resolution.

11  
12 According to a first aspect of the present invention  
13 there is provided apparatus for presenting a highly  
14 spatially accurate visualisation of a scene from which  
15 measurements can be taken, the apparatus comprising:

16  
17 at least one camera for recording a plurality of  
18 frames of video images of the scene;

19  
20 at least one sensor mounted in relation to the  
21 camera for recording sensor data on attitude and  
22 distance of the camera from objects within the  
23 scene;

24  
25 image processing means including a first module for  
26 synchronising the frames with the sensor data to  
27 form a corrected frame of preselected attitude and  
28 distance; and a second module for constructing an  
29 accurate mosaic from the selected frames; and

30  
31 display means for providing a visual image of the  
32 mosaic.

33

1 By first correcting the video frames prior to the  
2 mosaiced image being formed, distortions present in the  
3 frames recorded by the one or more cameras can be removed  
4 and so enhance the spatial resolution over the entire  
5 mosaiced image.

6  
7 Preferably the at least one camera is a video camera  
8 capturing 2 dimensional digital images.

9  
10 The at least one sensor may comprise any sensor capable  
11 of making a measurement relating to attitude or distance.  
12 Preferably the at least one sensor comprises a digital  
13 compass. Advantageously the digital compass records roll,  
14 pitch and yaw. Preferably also, the at least one sensor  
15 comprises an altimeter and/or bathymetric sensor.

16  
17 Advantageously the camera(s) and sensor(s) are mounted on  
18 a moving platform. In use the platform may be mounted on  
19 a vehicle to allow movement of the camera(s) and  
20 sensor(s) over the scene to be imaged.

21  
22 The apparatus may further include a calibration system  
23 from which the at least one camera is calibrated. In this  
24 way spherical lens distortion e.g. pincushion distortion  
25 and barrel distortion can be corrected prior to use of  
26 the camera(s). Further non-equal scaling of the pixels in  
27 the x and y axis is corrected together with a skew of the  
28 two image axis from the perpendicular.

29  
30 Advantageously the calibration system includes a  
31 chessboard pattern or regular grid. This provides for  
32 multiple images to be taken from multiple viewpoints so  
33 that the distortions can be estimated and compensated  
34 for.

1

2 Preferably the first module performs a perspective  
3 correction to the images using the sensor data.

4

5 Preferably the second module accomplishes video mosaicing  
6 via a correlation technique based on the frequency  
7 content of the images being compared.

8

9 Preferably also the apparatus includes a graphic user  
10 interface (GUI). More preferably the GUI is included with  
11 the display system. Advantageously the GUI includes means  
12 to allow a user to select and make measurements between  
13 points in the visual image of the mosaic. Optionally the  
14 GUI provides a user with means to control the movement of  
15 the at least one camera.

16

17 According to a second aspect of the present invention  
18 there is provided a method for presenting a highly  
19 spatially accurate visualisation of a scene from which  
20 measurements can be taken, the method comprising the  
21 steps;

22

23 (a) recording a plurality of frames of video images  
24 of the scene from a camera;

25 (b) recording sensor data on attitude and distance  
26 of the camera from objects within the scene;

27 (c) synchronising the frames with the sensor data  
28 to form a corrected frame of preselected  
29 attitude and distance;

30 (d) constructing an accurate mosaic from the  
31 selected frames; and

32 (e) providing a visual image of the mosaic.

33



1 Preferably the method includes the step of calibrating  
2 the camera prior to step (a). This calibration may remove  
3 distortion effects within the camera.

4

5 Preferably the step of calibrating includes the step of  
6 taking multiple images of a chessboard pattern or regular  
7 grid from multiple viewpoints and further estimating and  
8 compensating for the distortions.

9

10 Preferably the synchronisation step includes the step of  
11 performing a perspective correction to the images using  
12 the sensor data.

13

14 Preferably also the step of video mosaicing is achieved  
15 using a correlation technique based on the frequency  
16 content of the images being compared.

17

18 Advantageously the method further includes the step of  
19 taking a measurement from the visual image.

20

21 Optionally the method may include the step of storing the  
22 images so that they may be accessed by spatial position.

23

24 This method may advantageously be used to record crime  
25 scenes, accident scenes, archeological digs and the like  
26 where traditional methods of image recordal and distance  
27 measurement are time consuming. Additionally by storing  
28 the mosaiced images, distances previously not measured  
29 within the scene can be regenerated and accurately  
30 measured without having to reconstruct or preserve the  
31 original scene.

32

1 According to a third aspect of the present invention  
2 there is provided a method of performing an underwater  
3 survey, the method comprising the steps of;

4

5 (a) mounting a camera and a plurality of sensors on a  
6 platform capable of movement underwater;

7 (b) moving the platform through the water while  
8 recording visual images on the camera and taking  
9 sensor data relating to the attitude and depth of  
10 the platform from objects of interest within the  
11 water;

12 (c) synchronising the visual images to the sensor data  
13 to provide corrected visual images relating to a  
14 fixed depth and attitude;

15 (d) video mosaicing the images to form an accurate  
16 video mosaic as a visual image of the scene  
17 surveyed.

18

19 Preferably the method includes the step of precalibrating  
20 the camera to compensate for distorting artefacts  
21 inherent within the camera.

22

23 Preferably the method includes the step of displaying the  
24 visual image. More preferably the method includes the  
25 step of taking a measurement from the visual image.

26

27 In this way pipe spool dimensions can be taken underwater  
28 as can determination be made of the degree of damage or  
29 degradation of pipelines.

30

31 Advantageously the platform may be mounted on an  
32 autonomous underwater vehicle (AUV) or a remotely  
33 operated vehicle (ROV).

34

1 Preferably the apparatus comprises storage means to store  
2 the mosaiced images for viewing later.

3

4 Embodiments of the present invention will now be  
5 described, by way of example only, with reference to the  
6 following Figures, of which:

7

8 Figure 1 is a schematic diagram of a first  
9 embodiment of the present invention;

10

11 Figure 2 is a schematic diagram of a second  
12 embodiment of the present invention;

13

14 Figure 3 is a flow diagram depicting the stages of  
15 the sensor data integration with the algorithms  
16 required for the construction of the measurement  
17 mosaic of the second embodiment;

18

19 Figure 4 depicts a schematic of the camera pose  
20 alteration required to correct for perspective in  
21 each of the image frames by application of the pitch  
22 and roll sensor data in the second embodiment; and

23

24 Figure 5 shows a flow diagram of the method applied  
25 when correcting images for the sensor roll and pitch  
26 data concurrently with the camera calibration  
27 correction as in the second embodiment.

28

29 Referring initially to Figure 1 there is shown imaging  
30 apparatus, generally indicated by reference numeral 10,  
31 according to a first embodiment of the present invention.  
32 Apparatus 10 comprises a camera 12 mounted with sensors  
33 14,16. The camera 12 captures a series of frames of video  
34 images as the camera 12 and sensors 14,16 are moved over

1 an object 18. During this movement the sensors 14,16  
2 record data on the attitude and distance of the camera 12  
3 from the object 18. The sensor data and video images are  
4 input an image processor, generally indicated at 20. The  
5 processor 20 includes a first module 22 in which the  
6 frames are synchronised with the sensor data, as will be  
7 described hereinafter. The first module 22 outputs  
8 corrected video image from which is constructed a video  
9 mosaic in the second module 24, as described hereinafter.  
10 The video mosaic of the object 18 is displayed on a  
11 monitor 26 of a personal computer. Using a graphical user  
12 interface 28 of the personal computer a user can select  
13 points on the video mosaic and obtain distance  
14 measurements of the object 18. The measurements provide  
15 millimetre accuracy over 20 metre distances to the  
16 object. This is achieved by correcting variations in  
17 pixel dimensions with the sensor data and/or camera  
18 calibration, described hereinafter, and using the sensor  
19 data to also provide a determination of pixel dimensions  
20 in terms of real metric units.

21

22 Figure 2 depicts a schematic diagram of a second  
23 embodiment of the present invention illustrating the  
24 hardware and the high level processes. This embodiment  
25 consists of an instrumented camera platform, generally  
26 indicated by reference numeral 30, incorporating a video  
27 camera 32 which may be analogue or digital, a digital  
28 compass 34 and an altimeter sensor 36. The sensors 34,36  
29 measure the attitude (roll, pitch and yaw/heading) of the  
30 platform 30 and the distance from the camera platform 30  
31 to an object being viewed. In underwater applications,  
32 an additional bathymetric sensor may be used to measure  
33 the depth of submergence of the camera platform 30. Thus  
34 the platform 30 will be mounted on a suitable vehicle 35

1 e.g. underwater remotely operated vehicle (ROV), aircraft  
2 or even a hand-held mounting and moved across the scene  
3 of interest. As in the first embodiment, the video and  
4 sensor data is made available to the operator 37 of the  
5 system for live display. Additionally, the video and  
6 sensor data is stored 38 in a format which allows precise  
7 synchronization between the video and sensor data. The  
8 stored data 38 may be retrieved and used to construct a  
9 video mosaic image 40 representing a plan view of the  
10 scene being surveyed where pixel scale is maintained  
11 throughout the image. During the construction of this  
12 mosaic image corrections are applied to the video frames  
13 to correct the inherent distortions due to the video  
14 camera and to compensate for the effects of camera  
15 platform attitude and distance to the viewed scene.  
16 These corrections ensure that the constructed mosaic  
17 image 40 is an accurate representation of the scene being  
18 surveyed, with the relative scales and positions of the  
19 objects contained within the scene being preserved as  
20 well as possible. Once constructed, it is possible to  
21 obtain measurements 42 of objects contained within the  
22 mosaic image using a graphical user interface.

23  
24 Figure 3 depicts a flow diagram of the stages required to  
25 construct the video mosaic image. The first stage in  
26 this process is to acquire a frame of video data 50 and  
27 the corresponding sensor data 52 for this frame, from the  
28 storage unit 38. The video frame 50 is then corrected to  
29 compensate for the effects of the camera distortion and  
30 the camera platform attitude 54. This stage requires  
31 knowledge of the camera internal parameters which are  
32 estimated by a calibration method described later, and  
33 the pitch and roll angles 56 recorded by the digital  
34 compass 34. The corrected image 58 is then input into

1 the mosaicing procedure 60 where it is compared with the  
2 previous corrected video frame 50 in the video sequence.  
3 This procedure attempts to estimate the translation in x  
4 and y axes between the two frames by comparing the  
5 correlations between the frames in the frequency domain.  
6 The rotation between frames and the scale change between  
7 frames is determined from the compass heading and  
8 altitude/depth information 62. The next stage 64 is to  
9 apply the transformation parameters to the new frame and  
10 incorporate it into the final mosaic image 66, a process  
11 known as "stitching". Finally the pixel size may be  
12 determined by the use of a calibration target placed in  
13 the scene, or directly from the camera calibration  
14 parameters and altimeter sensor data.

15  
16 We shall consider the steps taken in the method in more  
17 detail. Beginning with the camera 32, all cameras suffer  
18 from various forms of distortion. This distortion arises  
19 from certain artefacts inherent to the internal camera  
20 geometric and optical characteristics (otherwise known as  
21 the intrinsic parameters). These artefacts include:

22  
23 (a) spherical lens distortion about the principal  
24 point of the system. The two common definitions  
25 for this type of distortion are pincushion  
26 distortion and barrel distortion;

27  
28 (b) non-equal scaling of pixels in the x and y-axis.  
29 This is arrived at through the estimation of the  
30 effective camera focal length in both the x and y  
31 pixel scales; and

32  
33 (c) a skew of the two image axes from the  
34 perpendicular.

For high accuracy mosaicing the parameters leading to these distortions must be estimated and compensated for. In order to correctly estimate these parameters images taken from multiple viewpoints of a regular grid, or chessboard type pattern are used. The corner positions are located in each image using a corner detection algorithm. The resulting points are then used as input to a camera calibration algorithm as well documented in the literature.

The estimated intrinsic parameter matrix  $A$  is of the form

$$A = \begin{bmatrix} \alpha & \gamma & u_0 \\ 0 & \beta & v_0 \\ 0 & 0 & 1 \end{bmatrix}$$

where  $\alpha$  and  $\beta$  are the focal lengths in x and y pixels respectively,  $\gamma$  is a factor accounting for skew due to non-rectangular pixels, and  $(u_0, v_0)$  is the principle point (that is the perpendicular projection of the camera focal point onto the image plane).

During the creation of the mosaic, the integration of the sensor data is performed in two phases; as is illustrated in Figure 4. The first of these involves the use of the pitch and roll measurements from the compass to perform a perspective correction on each of the frames prior the mosaicing procedure. A diagram showing the situation modelled by this correction is provided in figure 4. When correcting for perspective the new camera position is at the same height as the original viewpoint, not the slant range distance. Thus any correction for perturbations in pitch or roll will

1 not be misinterpreted as a change in camera height, which  
 2 may be considered either as a separate process handled  
 3 within the mosaicing procedure 60 itself, or gained from  
 4 the bathymetric sensor readings.

5  
 6 This perspective correction 54 is performed concurrently  
 7 with the camera calibration correction 55 following the  
 8 steps outlined in Figure 5. Figure 5 illustrates the  
 9 steps applied to all pixel positions in the corrected  
 10 image 58. Starting with the corrected image pixel  
 11 position 58, we obtain the corresponding pixel position  
 12 in the cameras true reference frame 82, we then obtain  
 13 the position in captured image distorted by the camera  
 14 calibration parameters 84, interpolate for value at  
 15 resulting subpixel level 86 and insert interpolate value  
 16 into initial corrected image pixel position 88.

17  
 18 Concatenating these two operations in this way saves on  
 19 both processing time and memory requirements. These  
 20 processes combine mathematically in the following way:

21  
 22 If  $\underline{u}$  is the corrected pixel position, the corresponding  
 23 position in the reference frame of the camera, normalised  
 24 according the camera focal length in y pixels ( $\beta$ ) and  
 25 centred on the principle point  $(u_0, v_0)$ , is  
 26  $\underline{c}' = [(c_1'', c_2'', c_3'')/c_4'' - (u_0, v_0)]/\beta$  where  $\underline{c}'' = PR_y R_x P^{-1} \underline{u}$ . The pitch  
 27 and roll are represented by the rotation matrices  $R_x$  and  
 28  $R_y$ , respectively, with P being the perspective projection  
 29 matrix which maps real world coordinates onto image  
 30 coordinates. Following this the pixel position in the  
 31 captured image is calculated as  $\underline{c} = A\tau_c \underline{c}'$ . The scalar  $\tau_c$   
 32 represents the radial distortion applied at the camera



1 reference frame coordinate  $c^i$ . The matrix  $A$  is as  
2 defined previously.

3

4 In estimating interframe mosaicing parameters of video  
5 sequences there are currently two types of method  
6 available. The first uses feature matching within the  
7 image to locate objects and then to align the two frames  
8 based on the positions of common objects. The second  
9 method is frequency based, and uses the properties of the  
10 Fourier transform.

11

12 Given the volume of data involved (a typical capture rate  
13 being 25 frames per second) it is important that we  
14 utilise a technique which will provide a fast data  
15 throughput, whilst also being highly accurate in a  
16 multitude of working environments. In order to achieve  
17 these goals, the preferred embodiment employs the  
18 correlation technique based on the frequency content of  
19 the images being compared. This approach has two main  
20 advantages; firstly, regions which would appear  
21 relatively featureless, that is those not containing  
22 strong corners, linear features, and such like, still  
23 contain a wealth of frequency information representative  
24 of the scene. This is extremely important when mosaicing  
25 regions of the seabed for example, as definite features  
26 (such as corners or edges) may be sparsely distributed;  
27 if indeed they exist at all; and secondly, the fact that  
28 this technique is based on the Fourier transform means  
29 that it opens itself immediately to fast implementation  
30 through highly optimized software and hardware solutions.

31

32 The second phase of integration is applied in tandem with  
33 the frequency correlation technique and incorporates both  
34 the altimeter and heading readings.

1

2 The mosaicing technique is capable of estimating the  
3 rotations between adjacent frames in the mosaic to an  
4 extremely high degree of accuracy. Unfortunately, the  
5 nature of the accumulation of the errors corresponds to a  
6 stochastic process called a "random walk". This has the  
7 effect of leading to a drift in the estimated track. For  
8 short range mosaics this effect is limited and may be  
9 discounted, thus allowing use of Fourier rotation  
10 measurements. However, for long range mosaics this will  
11 not be the case. In order to overcome this, the yaw data  
12 is utilised from the digital compass to provide a stable  
13 reference for the camera heading. This greatly increases  
14 the overall accuracy of the reconstructed mosaic.

15

16 For each image comparison, the interframe rotation and  
17 scaling values are obtained from the difference in the  
18 heading and bathymetric readings for that image pair.  
19 The second image is then corrected to the same  
20 orientation and scale of the first. This way only the  
21 translation in x and y pixels need be estimated. Having  
22 obtained the necessary parameters of the differences in  
23 position of the two images, they can be placed in their  
24 correct relative positions. The next frame is then  
25 analysed in a similar manner and added to the evolving  
26 mosaic image.

27

28 We shall now give a description of the implementation  
29 procedures used in this invention for translation  
30 estimation in Fourier space.

31

32 In Fourier space, translation is a phase shift. We  
33 therefore must utilise the differences in the phase to  
34 determine the translational shift. Let the two images be

1 described by  $f_1(x,y)$  and  $f_2(x,y)$  where  $(x,y)$  represents a  
 2 pixel at this position. Then for a translation  $(dx,dy)$  the  
 3 two frames are related by

$$f_2(x,y) = f_1(x+dx, y+dy)$$

4  
 5  
 6  
 7 The Fourier transform magnitudes of these two images are  
 8 the same since the translation only affects the phases.  
 9 Let our original images be of size  $(cols,rows)$ , then each of  
 10 these axes represents a range of  $2\pi$  radians. So a shift  
 11 of  $dx$  pixels corresponds to  $2\pi dx/cols$  shift in phase for  
 12 the column axis. Similarly, a shift of  $dy$  pixels  
 13 corresponds to  $2\pi dy/rows$  shift in phase for the row axis.

14  
 15 To determine a translation, we Fourier transform the  
 16 original images, compute the magnitude ( $M$ ) and phases  
 17 ( $\phi$ ) of each of the pixels and subtract the phases of each  
 18 pixel to get  $d\phi$ . We then take the average of the  
 19 magnitudes (they should be the same) and the phase  
 20 differences and compute a new set of real ( $\Re$ ) and  
 21 imaginary ( $\Im$ ) values as  $\Re = M \cos(d\phi)$  and  $\Im = M \sin(d\phi)$ . These  
 22 ( $\Re, \Im$ ) values are then inverse Fourier transformed to  
 23 produce an image. Ideally, this image will have a single  
 24 bright pixel at a position  $(x,y)$ , which represents the  
 25 translation between the original two images, whereupon a  
 26 subpixel translation estimation may be made.

27  
 28 It is not always that case that the peak is unique  
 29 however. When we have translation close to zero, the  
 30 gained true peak is often distorted by a secondary peak  
 31 at the origin. For this reason we place a lower  
 32 acceptance bound on the translation. If the gained

1 translation is lower than this, then the current new  
2 frame is discarded, and the next is compared to the same  
3 initial frame. This process has the added speed  
4 advantage that frames are only stitched into the mosaic  
5 if a reasonable translation has occurred.

6

7 A final point to note concerning this technique is that  
8 we must first window the intensity values to be Fourier  
9 transformed, ensuring that they are reduced to zero at  
10 the boundary. This removes the step discontinuities at  
11 the boundaries, making the periodic image, implied when  
12 stepping into the Fourier domain, appear continuous in  
13 all directions.

14

15 Following acquisition of the interframe mosaicing  
16 parameters it remains for the video images to be stitched  
17 into a single mosaic so that measurements between imaged  
18 positions may be achieved. This is performed using a  
19 similar philosophy to that adopted when correcting for  
20 perspective and camera calibration. Given a pixel  
21 position within the mosaic, what was the corresponding  
22 sub-pixel position in the original frame? The  
23 construction of the mosaic is also performed in such a  
24 way as to minimise the amount of memory required to  
25 contain the result.

26

27 In order to determine this mapping we first generate the  
28 camera track file containing the frame centre positions,  
29 orientations, and scale factors from the parameter file  
30 output by the mosaicing algorithm. This is done through  
31 accumulation of local translations, rotations, and  
32 scaling factors, each having undergone a rotation and  
33 scaling to make them local to the mosaic reference frame.

34

1 Following this, we may calculate the coordinates of the  
 2  $i^{\text{th}}$  frame pixel position  $(x_{fi}, y_{fi})$ , in terms of the  
 3 corresponding mosaic pixel position  $(x_m, y_m)$ , as

$$5 \quad \begin{bmatrix} x_{fi} \\ y_{fi} \end{bmatrix} = \frac{1}{z_i} \begin{bmatrix} \cos(\theta_i) & -\sin(\theta_i) \\ \sin(\theta_i) & \cos(\theta_i) \end{bmatrix} \begin{bmatrix} x_m - \frac{\rho_{ci} - 1}{2} \\ y_m - \frac{\rho_{ri} - 1}{2} \end{bmatrix} + \begin{bmatrix} \frac{f_c - 1}{2} \\ \frac{f_r - 1}{2} \end{bmatrix}$$

6  
 7 where  $\theta_i$  and  $z_i$  are the rotation and scaling values which  
 8 place the  $i^{\text{th}}$  frame into the mosaic, the size of area  
 9 required to fully contain the frame in the mosaic is  
 10  $\rho_{ci} \times \rho_{ri}$  pixels, and the original frame size is  $f_c \times f_r$   
 11 pixels. We then interpolate the sub-pixel value at  
 12 position  $(x_{fi}, y_{fi})$  in frame  $i$ , and place this value into  
 13 mosaic pixel position  $(x_m, y_m)$ .

14  
 15 Given the stitched mosaic it remains to make a  
 16 measurement between selected points in the final result.  
 17 In order to accomplish this, the pixel size must be  
 18 determined through use of either a calibration target  
 19 placed in the scene, or through use of the camera  
 20 calibration parameters and altimeter sensor data.  
 21 Following this calibration, the distance in pixels  
 22 between the selected points is multiplied by the true  
 23 distance subtended by each pixel to provide an accurate  
 24 length measurement.

25  
 26 The apparatus and method of the present invention lends  
 27 itself to the following applications particularly as  
 28 applied to underwater surveying:

29

1 (a) Metrology, through the measurement of physical  
2 dimensions in difficult to access environments;  
3

4 (b) Geo-referencing - in conventional video surveys  
5 the data is stored in a video format where each  
6 part of the survey is accessed by frame number.  
7 Under the present invention a survey can be  
8 stored as one or more mosaiced images which can  
9 advantageously be accessed by spatial position  
10 and integrated with other geo-referenced data  
11 such as maps, sidescan sonar, and engineering  
12 drawings;  
13

14 (c) Video compression - while video recording of a  
15 survey requires vast storage capacity and leads  
16 to data being stored on difficult to access  
17 magnetic tape media or in compressed forms on a  
18 computer, the present invention provides a  
19 compact data size as redundant information when  
20 images overlap is removed. This is done with very  
21 little degradation to the image quality compared  
22 to video compression methods. It is also possible  
23 to reconstruct a video of the original video  
24 survey; and  
25

26 (d) Navigation as the video mosaicing process  
27 involves the measurement of translations  
28 rotations and scalings that are present in the  
29 video sequence, the apparatus can provide  
30 navigational information about the platform on  
31 which it may be mounted. As the navigational  
32 information extracted from the video sequence may  
33 be extremely accurate (<1cm) over short ranges,  
34 the information can be used to aid positioning of

1 equipment, station holding and offers a potential  
2 benefit to the development of a synthetic  
3 aperture sonar system.  
4

5 The main advantage of the present invention is that it  
6 provides a video mosaic image from which measurements  
7 with millimetre accuracy can be taken. High spatial  
8 resolution is attainable by fusing the sensor data with  
9 the video images and then reconstructing the mosaic from  
10 a selected reference point. This allows measurements to  
11 be made from the video mosaic as the pixel dimensions are  
12 provided in terms of metric units scaled from the objects  
13 being surveyed. Use of a correlation technique based on  
14 the frequency content of the images being compared  
15 provides the advantages of allowing imaging of generally  
16 featureless scenes such as the seabed and as the  
17 technique is based on the Fourier Transform the data can  
18 be processed in real time through the implementation of  
19 highly optimised software and hardware solutions.  
20

21 Further the present invention provides advantages over  
22 traditional ways of obtaining measurements. Firstly, it  
23 may be used in environments where it is either hazardous  
24 or difficult to use conventional manual measurement  
25 methods. For example the measurement of pipeline spool  
26 pieces on the seafloor, can be conducted by mounting the  
27 camera and sensors on an ROV which can be flown over the  
28 two ends of the pipeline to be connected by the spool  
29 piece. Currently a method involving triangulation of  
30 acoustic transceivers is employed for this application.  
31 This is a time consuming method which requires the use of  
32 divers and some expert knowledge. A second advantage is  
33 that in the case of scenes containing a number of objects  
34 that must have their positions or separations recorded, a

1 survey can be conducted and the measurements made at a  
2 later time, with the minimum of delay incurred at the  
3 scene. This would be a considerable benefit in recording  
4 accident scenes or archaeological digs.

5

6 It will be appreciated by those skilled in the art that  
7 various modifications may be made to the invention herein  
8 described without departing from the scope thereof.



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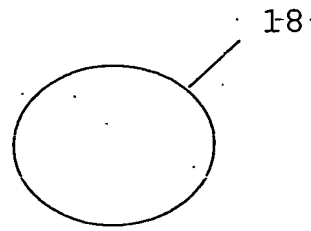
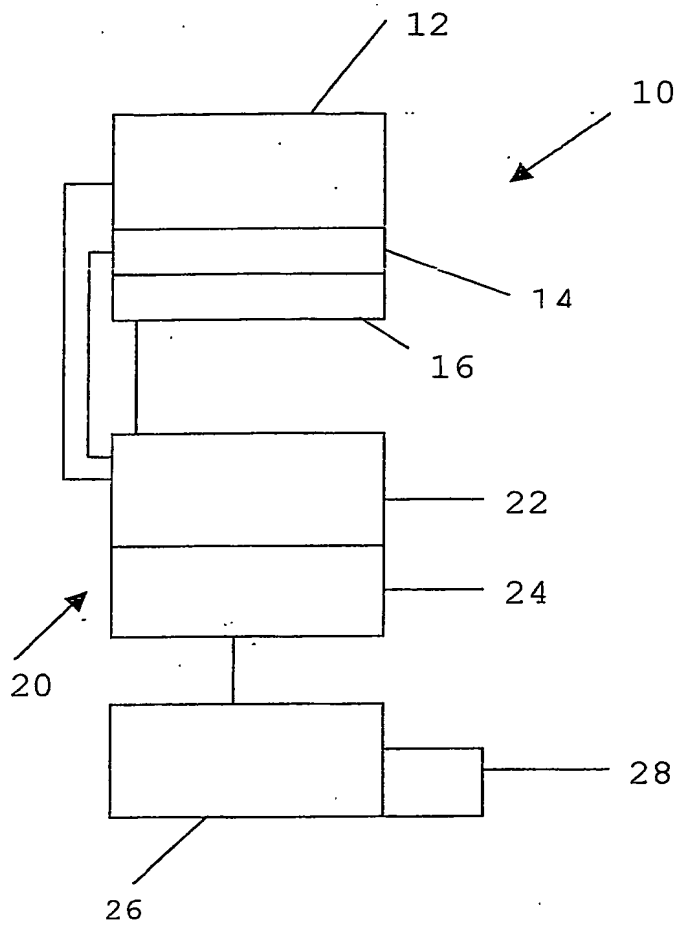


Figure 1

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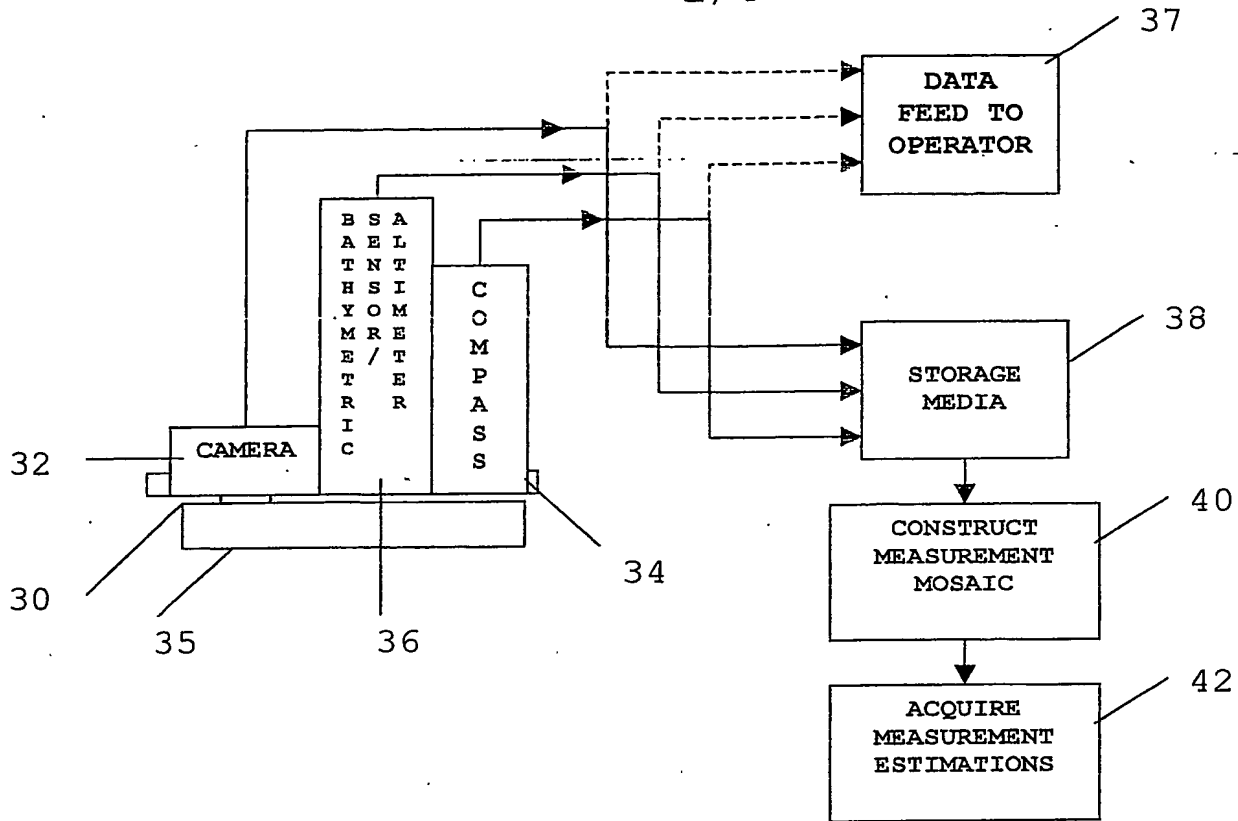


Figure 2

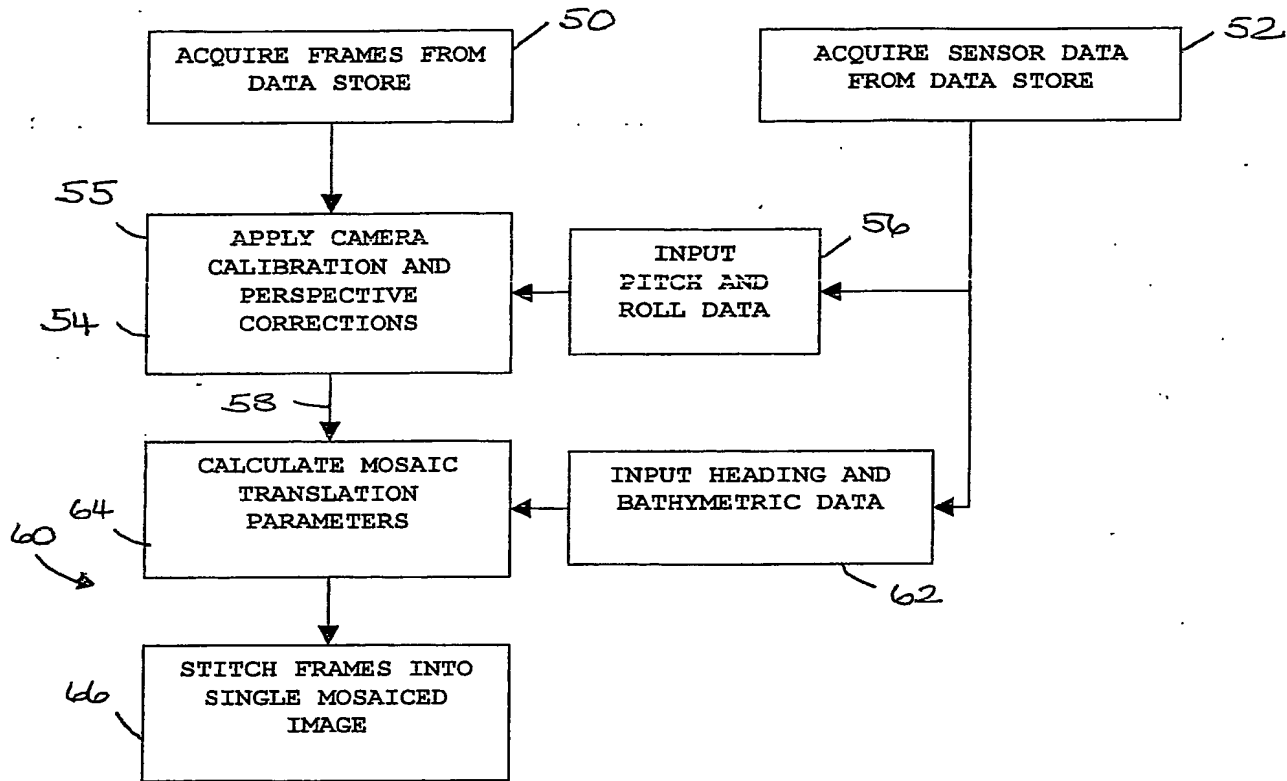


Figure 3

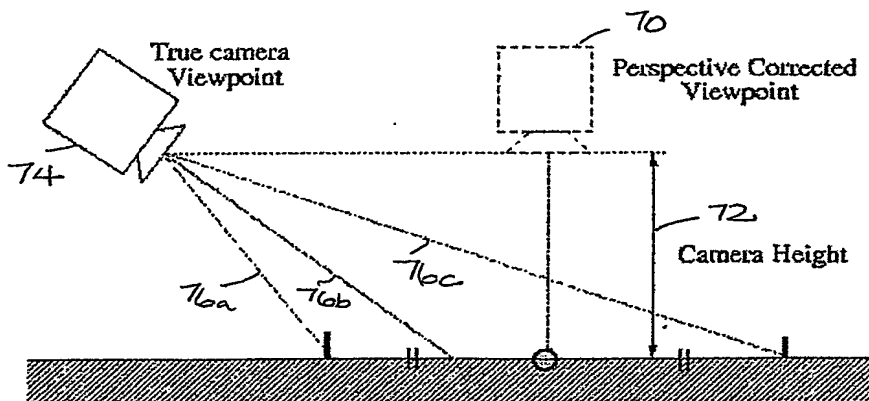


Figure 4

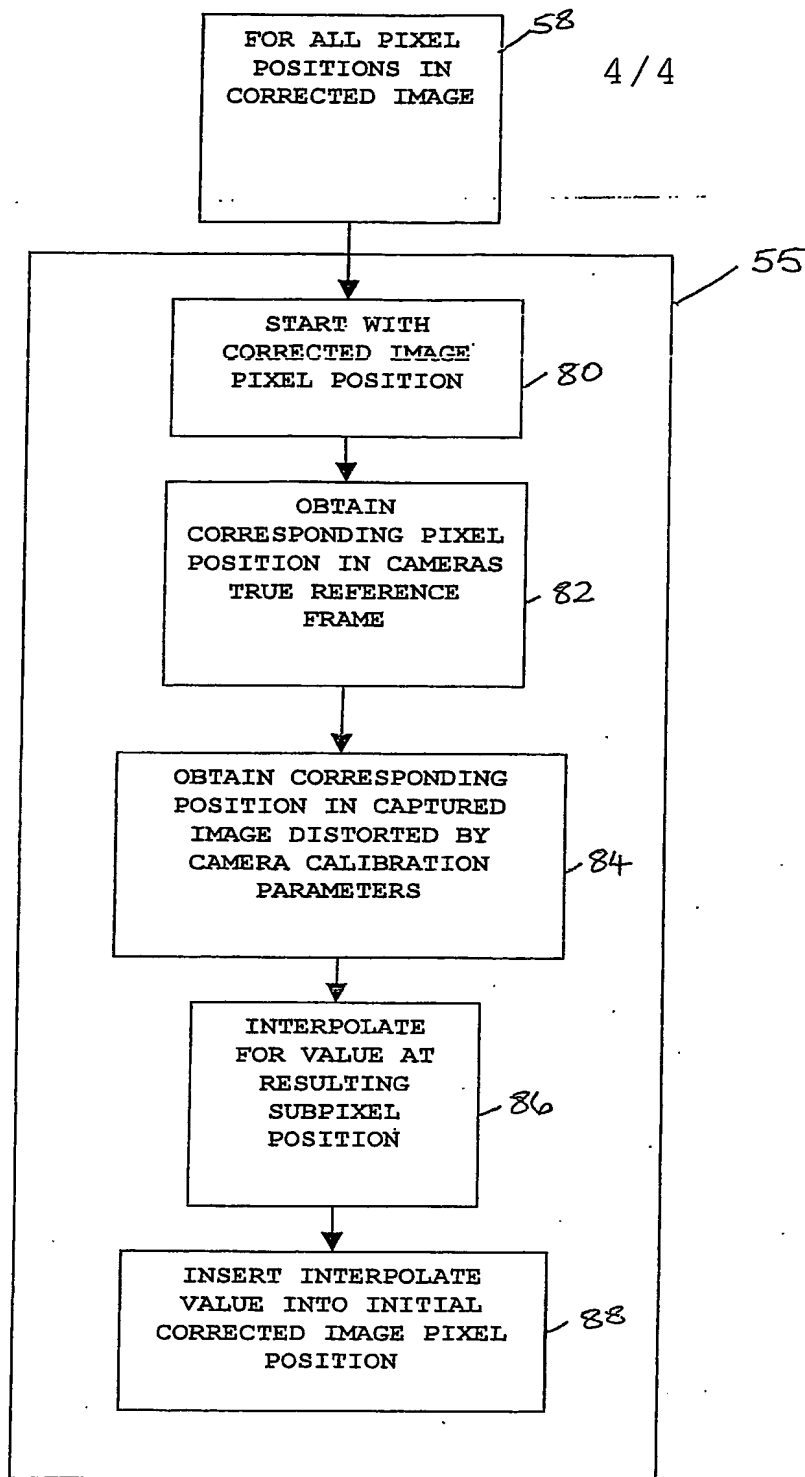


Figure 5

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